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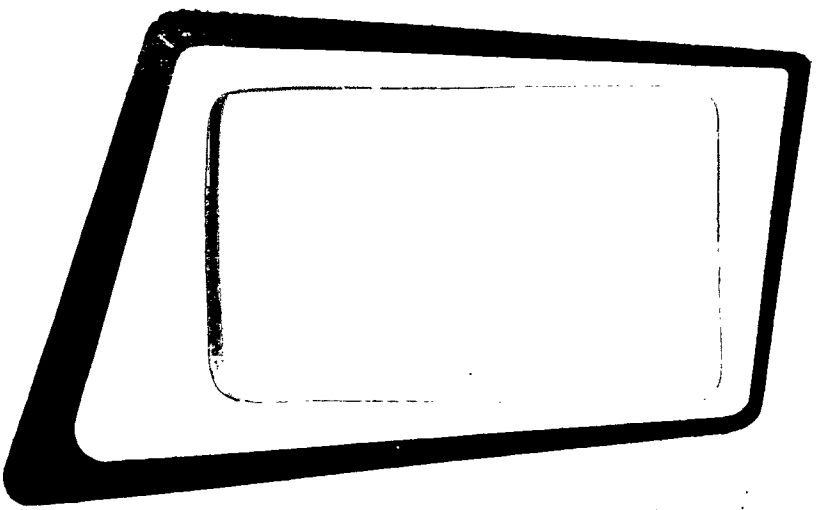

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Cumberland, Maryland

Operated by
HERCULES POWDER COMPANY

for
U.S. NAVY
BUREAU OF NAVAL WEAPONS
Contract NOrd 16640

ABL/E-87

A Temperature Measuring System Using RdF Stikon Resistance Elements

February 1, 1963

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Initial distribution of this report was made in accordance with the Joint-Army-Navy-Air Force Mailing Lists for Solid Propellants - dated June 1962.

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ABSTRACT

A temperature measuring system which uses RdF Stikon* nickel resistance thermometer elements (BN-200T series) has been developed at Allegany Ballistics Laboratory (ABL). This system was developed as the result of a recognized need for a high-output temperature transducer compatible with present four arm bridge systems.

The RdF Stikon was tested in a bridge circuit designed to simulate a standard 350 ohm four arm bridge.

The Stikon was found to be sensitive to strain. Since it was to be used on surfaces of unpredictable strain, a strain-free method of surface attachment was developed.

The complete system was tested and found to have a system error of less than two percent when used in the 32° to 432°F temperature range.

*Trademark of the RdF Corporation.

INTRODUCTION

Transducers are used at ABL for measuring various data from test firings. Examples of these data are pressure, force and strain. Standardization of the various types of transducers would permit more efficient use of the present four arm bridge transducer conditioning system.

The RdF Stikon discussed here is a temperature transducer. A bridge circuit will be shown which will "standardize" the Stikon so that it will be compatible with four arm bridge transducer conditioning systems.

The Stikon is a resistance thermometer designed to measure surface temperature (see Figure 1). The Stikon uses a fine C. P. nickle wire grid as a temperature sensor. The resistance of the wire grid varies with its temperature. Resistance values for an unmounted Stikon were supplied by the manfacturer for a temperature range of -100°F to +600°F (see Figure 2.) Since the recorders used to read the Stikon temperature are linear devices, the shape of the C. P. nickle curve in Figure 2 had to be modified from the existing positively increasing slope. Modification was attained with a bridge circuit having a similar curve but with a positively decreasing slope; thus, when a Stikon was used with the bridge circuit, by the principle of superposition a linear output resulted. The bridge circuit used in the Stikon tests is shown in Figure 3.

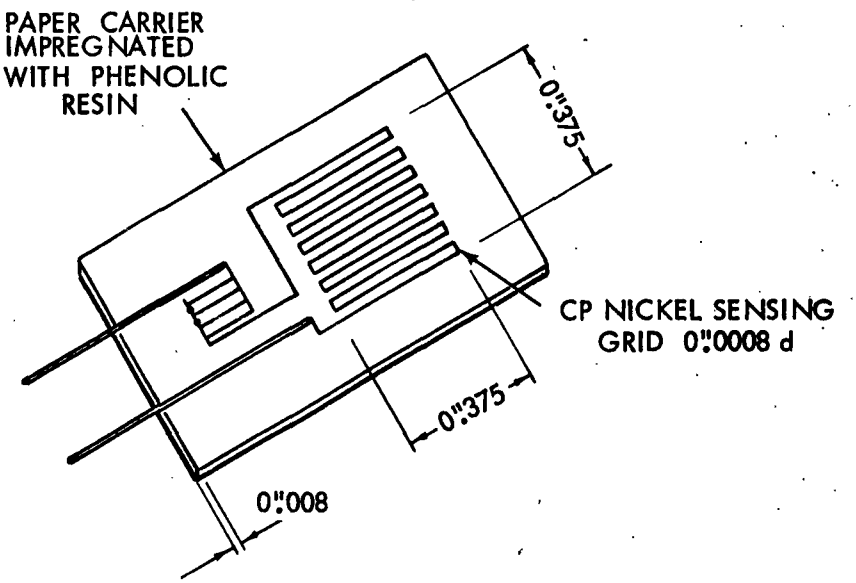


FIGURE 1
RdF Stikon (BN-200T Series)

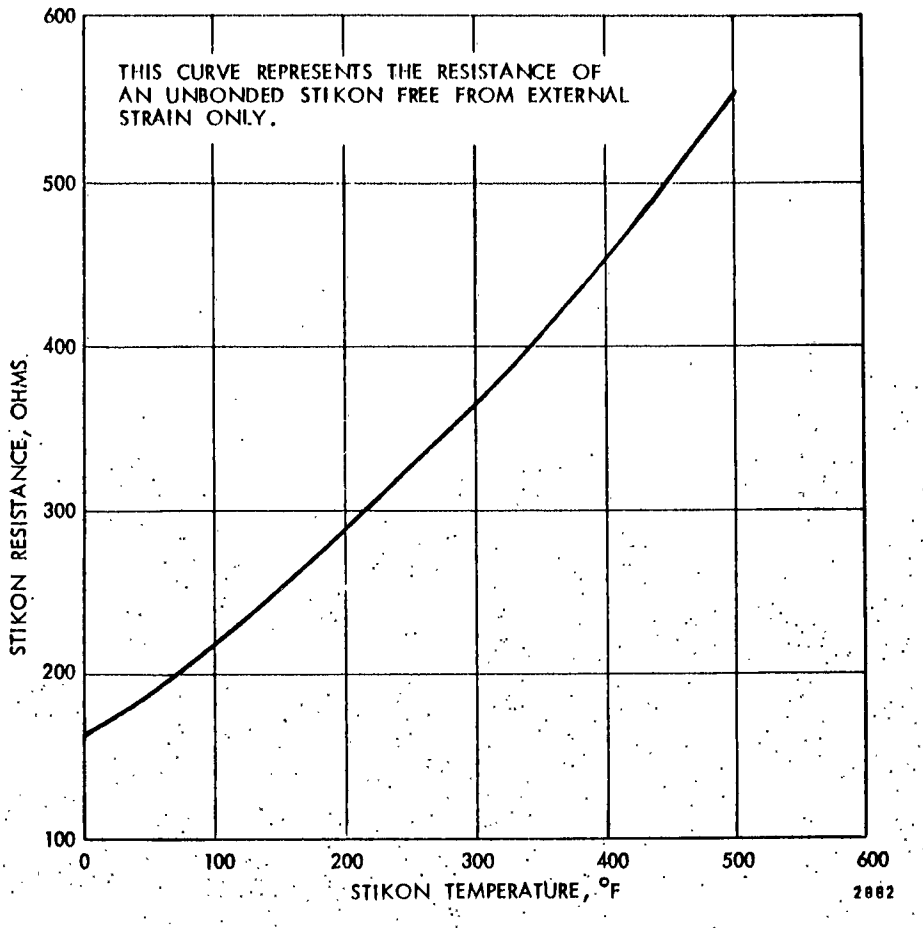
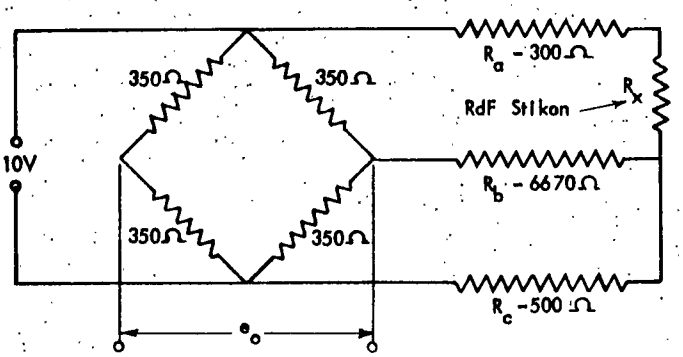


FIGURE 2
Resistance Change of an RdF Stikon (BN-200T Series)



R_a	R_b	R_c	Span
300Ω	6670Ω	500Ω	400 °F
300	3220	500	200
700	460	900	100

FIGURE 3
Bridge Circuit Used to Linearize the Output from an RdF Stikon

TEST PROCEDURES AND RESULTS

The component values used in the bridge circuit were experimentally determined by substituting potentiometers for R_X, R_A, R_B and R_C. Values that gave best linearity as read on the 3 mv/v. scale of a transducer calibrator were used. A four step calibration was used having 100 Fahrenheit degrees per step. This allowed measurement of temperature changes up to 400 Fahrenheit degrees. The bridge circuit was checked for linearity at balance temperatures of 32°, 70°, 100° and 125°F. The results of this linearity check are shown in Figure 4.

The accuracy of the system was checked by using the Stikons with the bridge circuit and recording the results using a transducer calibrator designed for shunt calibrating four arm bridges. Ten unmounted Stikons were immersed in a Hallikainen Silicone Oil Bath Oven. The Stikons were balanced at 125°F on the transducer calibrator and the oven temperature was increased to 350°F with readings taken at every 20 or 30 degree temperature increment with Tagliabue (TAG) Extreme Precision Glass Thermometers (calibrated in tenths of a degree). Data readings were made after the silicone oil oven had maintained temperature equilibrium, to the nearest hundreth degree, for a period of ten minutes. The test equipment is shown in Figure 5 and the results are given in Figure 6.

The Stikons were then bonded to a glass fiber specimen approximately 3 inches square and similar tests were run in the silicone oil oven. The ice point was used in these tests so that a more useful temperature range could be covered. The results of these tests (see Figure 6 and Table I) indicated that the resistance characteristics of the Stikons were affected by strain resulting from thermal expansion of the glass fiber specimen. This gave poor results with the bridge circuit which was designed to operate with Stikons having the resistance characteristics shown in Figure 2.

Several strain-free methods of attachment were tested in a effort to reduce the strain error. The results of 2 of the more pertinent tests are given in Table II. Mount #3 (Teflon*-covered Stikon) appeared to be the most satisfactory (see Table III).

TABLE I

Resistance Shift in the Bonded Stikon at 175.4 °F

Unbonded Stikon	Bonded Stikon #1	Bonded Stikon #2	Bonded Stikon #3
269.7Ω	273.6Ω	271.4Ω	273.6Ω

*duPont trademark.

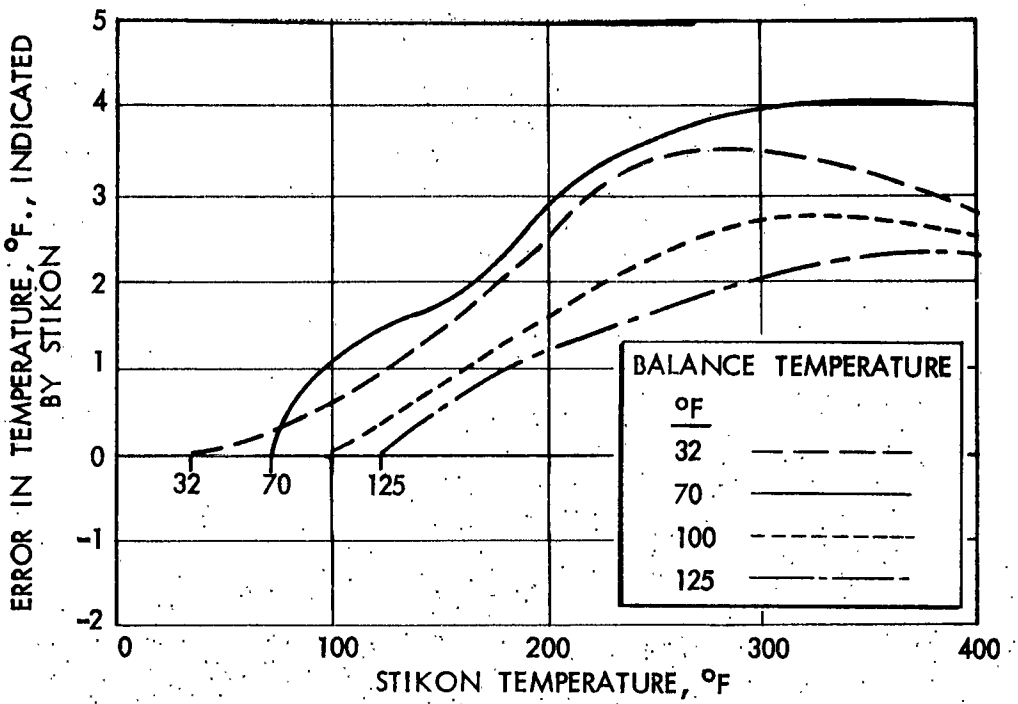


FIGURE 4
Linearity Curves for the Bridge Circuit (Using the Resistance Valves of a Freely Suspended Stikon)

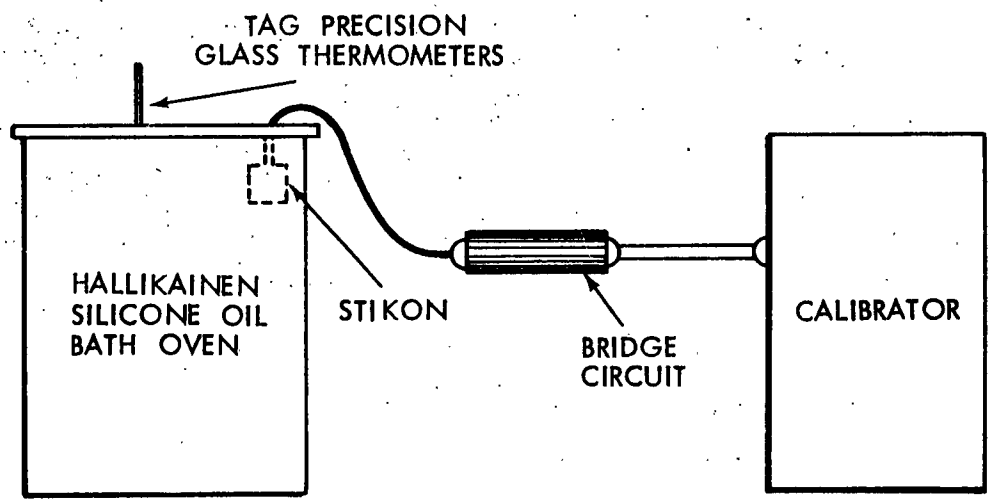


FIGURE 5
Apparatus Used In the Temperature Measuring System

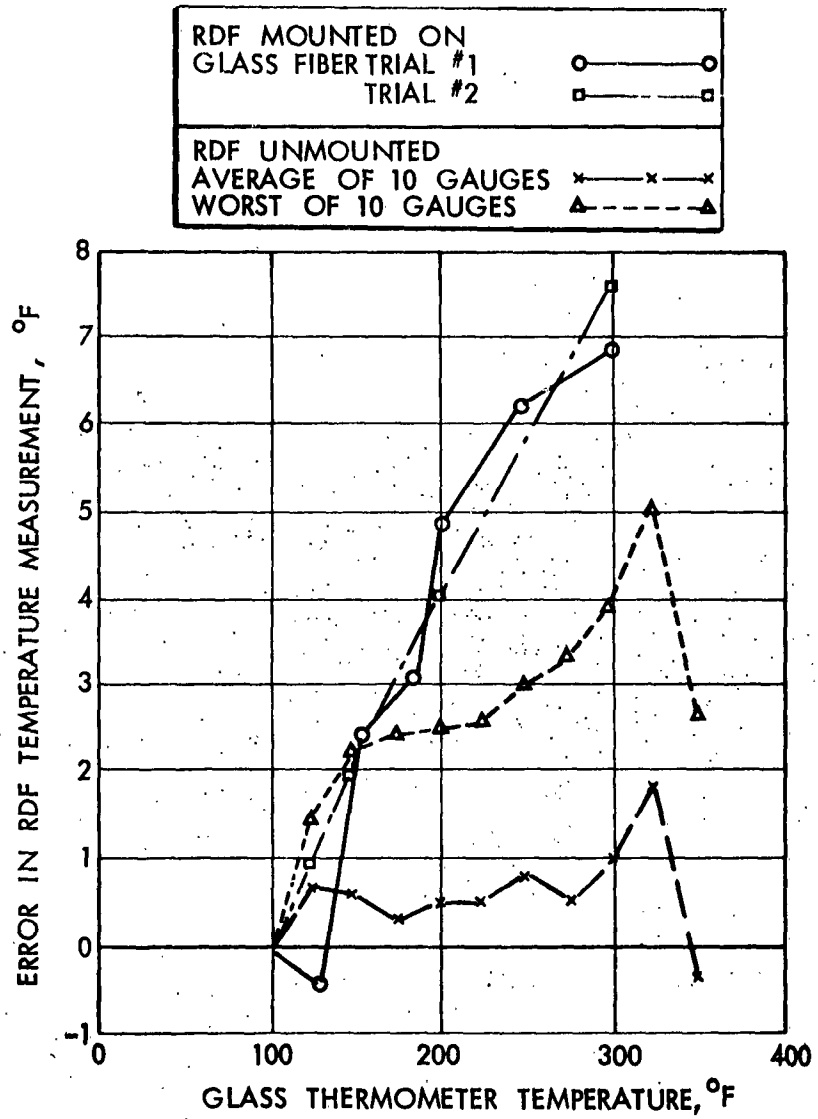


FIGURE 6
Comparison of the Accuracy of Unmounted Stikons to Stikons Bonded to Glass Fiber with Bakelite Cement

TABLE II

Methods Used to Mount Stikons to the Glass Fiber Surface

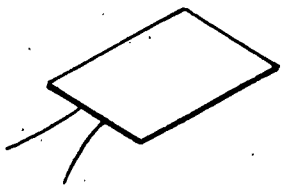
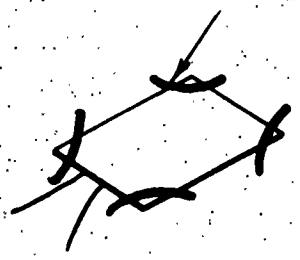
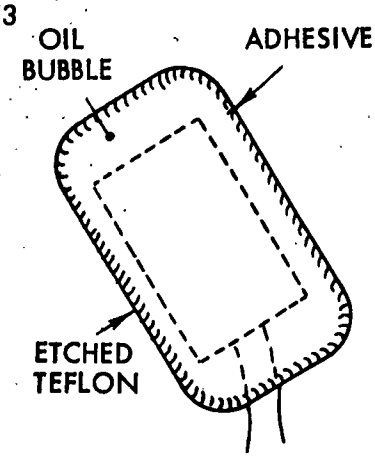
MOUNT	COMMENTS
#1  BAKELITE CEMENT UNDER ENTIRE STIKON	Good heat transfer, error resulting from thermal and physical strain (see Figure 6)
#2 SILICONE RUBBER OVER CORNERS  OIL FILM UNDER STIKON	Gave good temperature readings, but heat made gage curl away from surface giving poor heat transfer.
#3  TEFLON COVER WITH STIKON FREE FLOATING IN AN OIL BUBBLE	Good temperature readings (See Table III), oil insured a good thermal contact between Stikon and glass fiber. Not sensitive to strains and may be modified by adding a window over the sensitive wire grid. Teflon may be held in place with any contact cement or epoxy resin.

TABLE III

RdF Held to Glass Fiber with a Teflon Cover, Calibration Temperature at the Ice Point

Oil Bath Temperature	Temperature Indicated by RdF	Error	% Error
32.0°F	32.0°F	Calibration	—
64.0	65.0	+ 1	+ 1.5%
72.7	73.6	0.9	1.2
104.4	104.8	0.4	0.4
124.1	124.4	0.3	0.2
145.0	146.2	1.2	0.8
169.4	171.4	2.0	1.2
200.8	201.1	0.3	0.1
224.8	228.6	3.8	1.6
248.7	Pliobond Melted		

CONCLUSIONS AND RECOMMENDATIONS

The bridge circuit (see Figure 3) was designed to be used with Stikons having the resistance characteristics shown in Figure 2. Bonding the Stikon to a glass fiber surface altered its resistance characteristics giving poor results with the bridge circuit (see Figure 6 and Table I). The resistance characteristics of the bonded Stikons were affected by the bakelite cement curing temperature, Stikon orientation and thermal warping of the glass fiber specimen. These factors indicate a sensitivity to strains of a magnitude (0 to 1.5%) normally encountered in ABL rocket motor testing (see Figure 7).

Several strain-free Stikon mountings were tried with mount #3 in Table II being recommended. The Stikon was surrounded with a thin film of oil which provided good surface lubrication as well as good heat transfer. The Stikon was insensitive to surface strains when mounted in this fashion. This type of mounting allowed the bridge circuit to be used effectively with the Stikon and resulted in a system error less than two percent (see Table III) when the bridge circuit was balanced at the ice point. If the balance point is 125°F, results similar to those of Figure 6 (unbonded Stikon) will be obtained. The two percent error was attributed to residual non-linearity in the bridge system (see Figure 4) and nominal resistance variation between Stikons.

Stikons used as described above are capable of measuring temperatures from 32°F to 432°F with an overall system error less than two percent even when large strains are present.

REFERENCE

1. F. R. Maslen, "Note on the Strain Sensitivity of Platinum and Nickel in the Range 50° to 650° C, "Strain Gage Readings, Vol. 3, No. 6 (1961), Review 824, pp. 26-27.

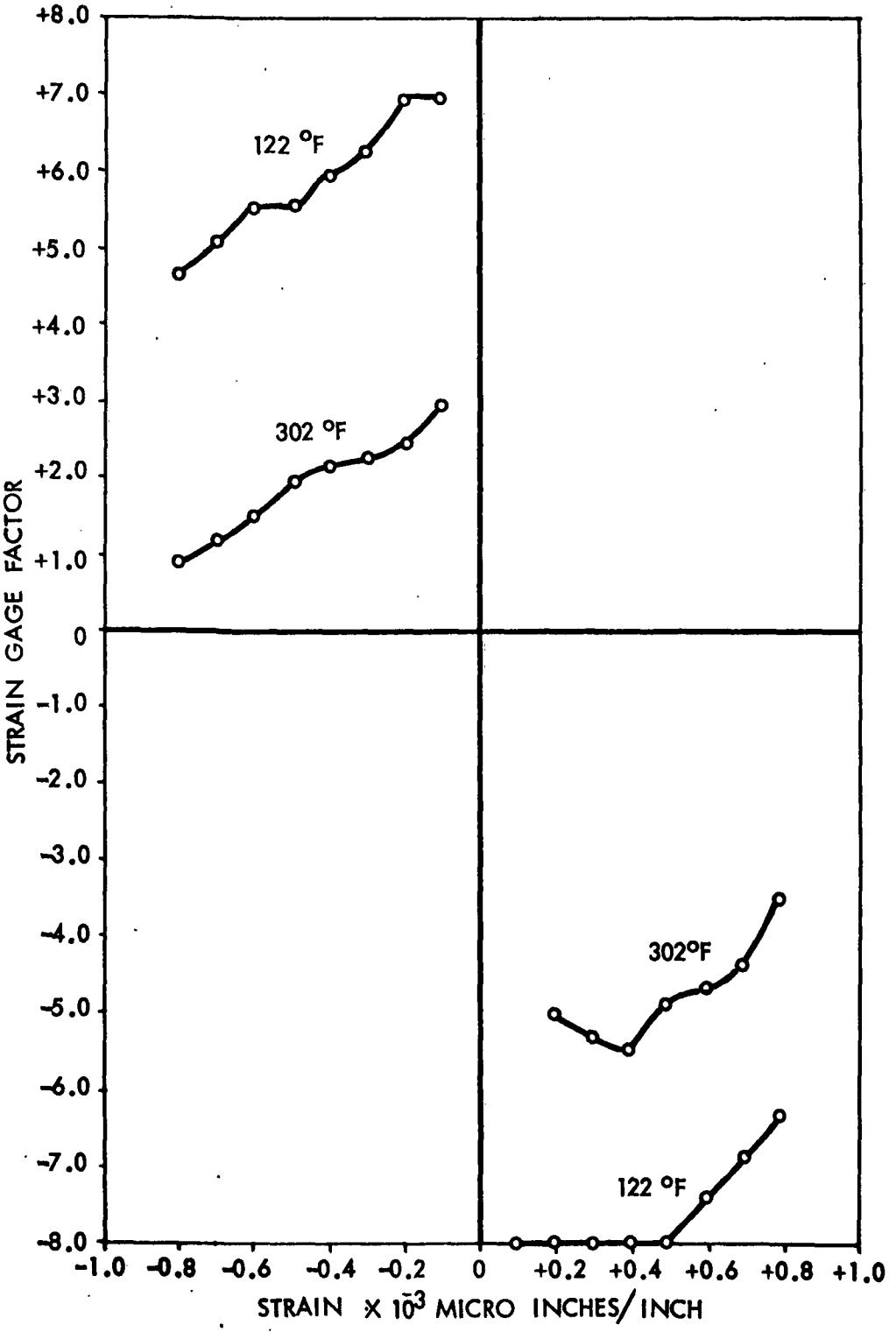


FIGURE 7
Strain Sensitivity of the C.P. Nickel Sensing Grid Used in an RdF Stikon[1]

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